DISCUSSION ON

"THE TESTING OF COMMUNICATION-TYPE RADIO RECEIVERS"*

BEFORE THE RADIO SECTION, 3RD MARCH, 1948

Dr. D. G. Reynolds: I think that the authors have done a very useful piece of work in bringing together in one document a preliminary selection of the tests that they consider useful for the design-acceptance or production-sampling of communication receivers. A Committee of the British Standards Institution (*ELE 23/8*) is at present considering methods of testing the performance of radio receivers, and much of the procedure described in the paper will become the subject of the Specification that the Committee will eventually produce. The authors have given several possible targets, especially where they have produced new definitions of their own. I like the definition of a.g.c. threshold, which is much better than the one normally used (i.e. producing the a.g.c. curve backwards and the uncontrolled curve forwards and using the cross-over point). The authors' suggestion of 1-db change of output for 2-db change of signal is a good one. They define, I think for the first time, the strength of the blocking signal as that which will give a 3-db drop in the wanted signal.

The Radio Industry Council has suggested a rather simpler dummy-aerial scheme than the one described in the paper. It is proposed that there should be two dummy aerials: below 2 Mc/s the aerial should have 25 ohms, 20 μH and 200 $\mu\mu$F in series; and over 2 Mc/s, simply 400 ohms.

In Section 3.5.1 the authors say, "For a loudspeaker with a satisfactory response the sound pressure increases at a rate of about 2½ db per octave." Depending on the sort of high-note distribution which the loudspeaker may have, one may or may not want 2½ db per octave. If it has a very good high-note distribution, a rather lower figure will be required.

In Section 3.11.1 the authors say, "Overloading of the stages preceding the detector should not occur under the conditions of normal operation with an effective a.g.c. system." That is true, but if an overcoupled circuit is used in the anode of the last i.f. valve, the impedance presented is always rather low, and it is not uncommon to find receivers in which the last i.f. valve is not capable of working at high modulation depths. Automatic gain control on that valve makes matters considerably worse, because its output-handling capacity is very much reduced when it has a large bias from the a.g.c. line.

In Section 3.12.2 the authors state that the a.f. gain control should be at such a setting that overloading of the output stage does not occur with an input to the receiver of 0·1 volt. I am not altogether in agreement with that. The method is a good one for receivers with good automatic gain control, but in some simpler receivers the a.g.c. is not so good and rather small outputs at low inputs occur. I prefer the method whereby the test is started at low inputs with the volume control at the full-gain position. As the input is increased, a point is reached beyond which there is some danger of overloading, and at that point the volume control is reduced by 10 db; the input is then further increased until it is (perhaps) necessary to reduce it by another 10 db, and so on. I think that the a.g.c. characteristic might be carried on to, say, 1 volt; in Welwyn Garden City, for instance, only five miles from Brookmans Park, signals over 0·1 volt have to be considered. It is also worth while to carry the a.g.c. characteristic to 1 volt if it is suspected that there is rather too much a.g.c. control in the last i.f. valve.

With regard to Section 3.14.2, it may be outside the scope of these tests, but I think that, in assessing whether communication receivers are well designed, a temperature-rise test should be made on various parts of the set. It is not unusual for designers to put the oscillator circuits of the set in a far hotter situation than is necessary, thereby increasing the temperature drift of the set. Part of the goodness of design of a set lies in its layout. It is useful, in assessing the reliability of a set, to consider the temperature rise of other components, such as electrolytic capacitors and mains transformers, because these may have considerable effects on reliability.

With regard to Section 3.18, I agree with the authors' definition of the causes of inaccuracy. We came to the conclusion that it was better to have a movable cursor and to set the cursor accurately by a built-in crystal oscillator, thus reducing scale errors to a minimum.

I feel that in testing a set of this kind it is very important to carry out life tests on the mechanisms used. Tuning backlash may be quite small on a new set, but it may increase rapidly when the set is in use and the mechanism wears. Turret assemblies may develop contact troubles during life, and this may lead to calibration errors, while both turret and switch contacts may give considerable noise troubles after a few months or a few years of life. Mechanical tests should be included in any system of acceptance testing.

Mr. W. P. Anderson: As the measurements described appear to be of an accuracy considerably greater than is obtainable with the instruments that are normally available in a receiver laboratory, it would be of value if some information could be given about the precautions taken to ensure the accuracy of the instruments used.

The tests described measure precisely the performance of the receiver when new, but of much greater interest to the user is the average performance during the period between overhauls, and the length of this period. It is by no means certain that the receivers tested would rank in the same order as before if judged on this criterion.

Extensive use is made in the paper of the expressions "signal/noise ratio" and "noise factor." These expressions, although well established, are essentially somewhat complex, and it is not clear what advantage is gained by this complexity. It appears that the noise performance of a receiver could very well be expressed, in absolute terms, as the noise power, per cycle bandwidth, due to causes other than thermal agitation in the input resistance, referred to the input circuit.

Mr. F. M. Colebrook: At present there are no British standards for the testing of receivers. The need for such standards became very evident during the war, particularly in our co-operation with America. At one time, for example, two definitions of noise factor were in use, which led to differences of 6 db in the assessment of the signal/noise ratio of certain receivers. The Americans therefore tried to produce the necessary standard definitions, and we on our side tried to do so too. A Panel was set up by the Inter-Service Radio Measurements Committee, which began

* Paper by W. J. BRAY and W. R. H. LOWRY (see 1947, 94, Part IIIA, p. 313).

work in September, 1945. As the outcome of the work, there will soon be in existence an inter-Service glossary which will contain agreed standard definitions of characteristics of receivers of all types and of all frequencies.

We realized, of course, that such a glossary would not be a national standard, and we therefore took the necessary steps to resuscitate the work of the British Standards Institution in this field. The inter-Service document has been of very great help in this work, and the first draft of the corresponding British Standard has been practically completed. We found very early that for work of this kind it was necessary to recognize two quite distinct types of definition. Definitions of certain receiver characteristics already existed in the B.S.I. Glossary of Terms used in Telecommunication, but, when we examined them from the point of view of using them as the basis of test procedures, we found they were not suitable for this purpose. They are what may be called qualitative definitions. For example, selectivity is defined as "the ability of a receiver to discriminate between wanted and unwanted signals." That is quite true, but it does not specify a quantity that we can measure; in such cases we therefore had to frame the definitions in such a way that every one of them described unambiguously a measurable quantity or series of quantities by which the characteristic concerned could be rated.

I should make it quite clear that the documents I have mentioned refer to a receiver considered as a box containing electrical components, with input and output terminals; in other words, we have not so far included the rather difficult and incompletely explored field of presentation. Preparations are being made for the completion of the work in respect of this essential element of the receiving installation.

These definitions, in view of the generality of their application, are of necessity cast in a very general form, so much so, that if one were primarily concerned, for example, with broadcast receivers, one might find it difficult to draw up a specific and detailed schedule simply by using this document. For that reason we are seeking the collaboration of the Radio Industry Council in drafting an Appendix, or an application document, associated with the general definitions, in which the general definitions will be given the particular form which is most appropriate to that particular class of receiver. Similar documents will no doubt be required for other classes of receiver.

Mr. H. V. Griffiths: We have found that the results of receiver tests, if expressed graphically in the form of vertical lines of length corresponding with, for instance, the measured signal/noise ratio, enable rapid comparisons to be made of the relative goodness of different types of receivers. Some standardization of the methods and input levels of measurements is obviously essential for such comparisons. I notice that P.O. engineers measure the input voltage required to reduce the noise output of receivers by 15 db. We have, in the past, standardized the figure of 10 db. Neither figure has any special virtue to recommend it. One could quite well argue in favour of a greater noise-ratio, because a noise background of − 10 or − 15 db is too great for tolerable relay reception. I agree with the authors that there is much to be said in favour of measuring the noise factor, as described in the paper.

There should be no doubt whatever regarding the practical value of all these tests. For instance, the problem of cross-modulation may be a very real one at a receiving station. We had to contend with a local transmission the field strength of which was, for a short period, approximately 1 V/m and which has since been reduced, but is still never less than 100 mV/m. Laboratory tests of different receivers show quite large differences in the input-signal level required to produce audible cross-modulation. The differences between similar receiver designs are sometimes unaccountable. I have in mind two types of communication receivers with practically identical circuits and valves. The input level which causes appreciable cross-modulation is in the one case 100 mV and in the other case 500 mV. This difference had not been suspected to exist before the laboratory tests were made.

Referring to the test of tuning drift, mentioned in Section 3.14.2, and to Fig. 21, the drift curves of the receiver are, I think, exceptionally good. Drift curves taken over fairly short periods in the laboratory sometimes fail to tell the whole story. In this respect, I recommend strongly, as the result of practical experience, that the laboratory measurements should be supplemented by operating tests with the receiver actually in constant use. Nowadays, at the conclusion of actual measurements we invariably hand a receiver over to the operating staff for about a week before making a final report upon it. In one recent case we had a batch of receivers of one type which passed all their laboratory tests very well. Tuning drift appeared to be well within the usual limits. During the operating tests a serious fault was demonstrated, which took the form of discontinuities in the drift curve after the receiver had been switched on many hours. The receiver tuning jumped suddenly by about 10 or 20 kc/s. There was no sign of this fault in the laboratory tests, perhaps because the range of ambient temperatures in the laboratory was less than that experienced under normal 24-hour-operating conditions.

Mechanical design faults do not always show up during laboratory tests, but some tests for these can be specified without difficulty. Backlash in the tuning controls is a suitable example. We have tested one type of receiver that was in other respects well designed, in which backlash in the tuning scale had received the designer's careful attention, whereas the backlash in the drive between the dial and the tuning condenser appeared to have been neglected.

Mr. F. D'Souza: I suggest that a more appropriate title for the paper would have been "Tests or Measurements on Communication-Type Radio Receivers." According to the authors' title, the testing of receivers ought, I feel, to have been divided into three broad groups: first, first-model or sample testing by a client; secondly, production testing, i.e. testing of receivers that have come off the assembly bench; and thirdly, routine testing of sets in service.

Referring to Sections 2 and 3, certain test equipment and tests are, to my mind, a common denominator to the three groups I have mentioned, and certain others, for instance items (*e*) and (*g*) of Section 2, are superfluous for routine and even for most production testing; item (5) of Section 3 is surely the exception rather than the rule, as I see no useful purpose in applying this test to communication-type receivers. I suggest that an i.f. alignment oscillograph should have been included in the list. Most communication receivers use one or more crystals in the i.f. pass-band filters, and for ease of adjustment such an alignment oscillograph would be invaluable. In fact, with a suitably calibrated scale in front of the oscillograph, the i.f. frequency-response characteristics could be determined. The principle of operation of the oscillograph is as follows. A time-base generator of low velocity and recurrence frequency provides the X-axis deflection of the c.r. tube and at the same time frequency-modulates an oscillator (of i.f. frequency) whose output is applied to the system under test; after amplification and rectification, the output of the system under test is applied to the Y-plates of the tube, and by this means the i.f. response curve is traced on the screen.

A point-to-point or circuit check should be carried out on the receiver before any one of the tests mentioned in Section 3 is applied.

For obvious reasons, production tests have to be carried out n the following order: (*a*) l.f., (*b*) i.f. and (*c*) h.f. circuits, and nder these conditions the term "testing" generally implies lignment as well as measurement.

Referring to Section 4, can the author give some information egarding the suppression of mains-borne interference, especially f the order of 30 kc/s and below?

Mr. J. D. Holland: I think that some reference to the measurement of input impedance would have been of value. Some eceiver specifications prescribe that the input impedance should e sensibly constant at a value of 75 ohms, but measurements ave shown that the input impedance is often inconstant with alues varying between 100 and 300 ohms over the frequency ange. Such values of mismatch are undesirable, although an ncrease in signal/noise ratio of 1 or 2 db can be obtained when neasurements are made at the receiver input terminals with a 0-ohm terminating resistance.

One method of measurement is shown in Fig. A(i). The

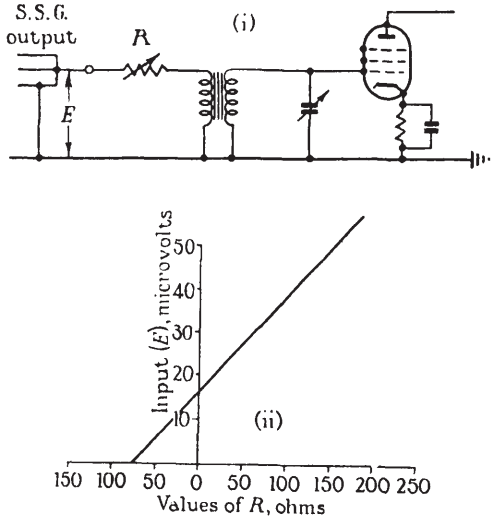

Fig. A.—Measurement of input impedance for resistive sources.

$$R_x = \frac{E_2R_1 - E_1R_2}{E_1 - E_2}$$

put circuit of the receiver is terminated in a variable resistor R, nd readings are taken as follows: Let E_1 correspond to one alue of R, say R_1, for a certain output at the second detector, nd E_2 correspond to another value of R, say R_2, for the same utput, then the input impedance, R_x, is given by the equation own in Fig. A(ii).

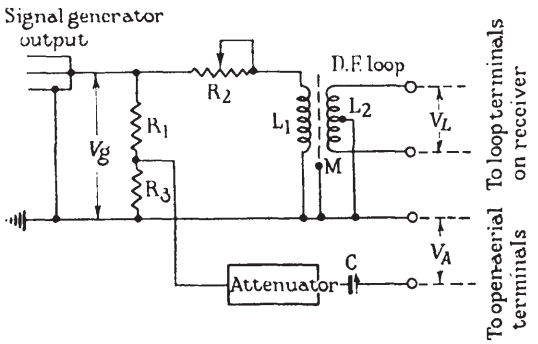

Fig. B.—Test circuit for d.f. receivers.

E.H. of loop = 2 cm at 1 Mc/s.
$R_2 \gg XL_1$ $V_A = 50V_L = V_g/10$ $[R_2 = 500 \cdot 2\pi fM]$
Field strength, μV/metre = 1/10th of s.s.g. readings.
R_2 variable for measurements at other frequencies.

In Section 2.3, the authors refer to the use of an induction-field generator for measurements of receivers fitted with loop aerials. An alternative measurement technique, which we have developed, may be of interest. The circuit is shown in Fig. B. The output of the signal generator is fed into two circuits in parallel, which present to the generator a constant impedance that is large compared with the output impedance of the generator. One of these circuits consists of a variable condenser C and an attenuator. The other circuits consists of the shielded loop L_2 and one or two turns of wire tightly coupled to the loop, forming the inductance L_1. The chief design points are as shown in the Figure and based on a loop aerial that has an effective height of 2 cm at 1 Mc/s. R_2 was chosen so that the e.m.f. available in the open-aerial circuit, with no attenuation, was 50 times that produced across L_2, and 1/10th of that provided by the generator. Hence this condition corresponds to that of an effective height of 1 m, and the equivalent field strength in microvolts per metre is 1/10th of the readings of the generator in microvolts. The value of R_2, which must be large compared to the primary reactance of L_1, is calculated from the known values of M and the frequency of measurement. The values of R_1 and R_3 are 90 and 10 ohms respectively. The whole of the circuit shown in Fig. B is mounted in a screened box with coaxial outlets to the loop and open-aerial terminals of the receiver under test, and rapid tests to stimulate various effective heights and orientations under working conditions are possible. This method of measurement was, I believe, first developed by the R.A.E., who used a small variometer, simulating the actual loop in use, for L_1 and L_2.

Mr. M. G. Scroggie: The British Standards Institution appear to intend to standardize two dummy aerials, one for working above 2 Mc/s and the other for working below 2 Mc/s, but there seems to be no technical reason to justify the considerable trouble of changing the dummy aerial whenever the 2 Mc/s boundary is crossed, or the liability to errors through forgetting to do so. The standard circuit of Fig. 1 has long been widely used and seems to fulfil the requirements.

Many of the most important tests described in the paper require measurement of output of both signal and noise, and the authors refer briefly, in Section 2.5, to the fact that the output-power meter should be linear for power; I think that, in view of the importance of this point, they might have gone a little further into it, because the rectifier type of meter commonly used is approximately linear for voltage, and errors with non-sinusoidal waveforms may be large. A valve can be selected and operated to give a nearly linear power characteristic, but it is inconvenient to use. How do the authors overcome this difficulty?

In Section 3.1.2, the authors say: "If the receiver gain is inadequate to produce the standard output with a 15-db signal/noise ratio, the sensitivity is determined by the input required for the standard output." I presume it is at the maximum gain and not at the adjusted gain used for the other tests.

The first slide shown by the authors dealt with interference by i.f. harmonics, but I have been unable to find any reference to it in the paper itself, and, as it is not covered by the method of measurement of "Other Unwanted Responses," I think it might receive special mention. This type of intereference is a maximum at the threshold of the automatic gain control, because up to that point the strength of the harmonics generated by the detector increases with the signal strength, and beyond it the strength of harmonics is held more or less constant while the gain is reduced. I therefore suggest that the receiver should be tuned to the various harmonics of the intermediate frequency, and the interference output measured at the a.g.c. threshold, which can be determined according to Section 3.13.

In Section 3.13.2, the authors say, "the a.f. gain control should be at such a setting that overloading of the output stage

does not occur." No definition is given of the overloading point, and I think that, in place of the fidelity curve, which seems hardly necessary for communication receivers, there ought to be some test to determine the overloading point and hence the a.g. outputs.

Another test, which is especially important in h.f. receivers with loadspeakers, is for liability to acoustic feedback. Have the authors evolved a satisfactory test procedure for it?

Group Captain P. Allerston: I should like to refer to Dr. Reynolds's oral statement that the Wireless Telegraphy Board Specification No. K114 demands a maximum temperature of 70° C for the components and only 50° C (122° F) for the equipment. This means that an equipment could be unserviceable for at least 30 days in the year, and probably more, at many points east of Suez. Perhaps Dr. Reynolds would like to comment further.

Far be it from me to criticize the technical quality of the paper, but I should like to join with Messrs. Griffiths and D'Souza in saying that I think that either the paper is far from complete or else its title is wrong. The title seems to me to be misleading in that it refers to "The Testing of Communication-Type Radio Receivers," whereas the paper deals only with laboratory tests. We must not forget the operational requirements or service trial procedures to which Messrs. D'Souza and Griffiths refer. I feel that these subjects should have been included: alternatively, further papers should be written on these larger aspects.

Mr. R. B. Armstrong: This critical review of current practice of laboratory testing of receivers is opportune in view of the post-war resuscitation of activity by both national and international committees in connection with co-ordination of testing and specifying the performance of receivers.

It is important that such activity should differentiate sharply between the testing of receivers for the three main purposes, namely to satisfy the designer that the basic design reaches minimum design standards; to satisfy the production engineer that the average product differs from the prototype by not more than a specified tolerance; and to satisfy the user of the suitability of the design for his particular applications.

A brief consideration of the specification of sensitivity in the light of the above shows the necessity for clarity as to which of the three categories is considered. For the purposes only of laboratory discussion of designs, the noise-factor aspect is the most desirable criterion by which the useful sensitivity may be assessed. The authors show (Fig. 19) another conventional presentation of sensitivity, from which the user can read off directly, for any given range of inputs, the range of outputs and signal/noise ratios to be expected, which is of much more direct interest to the communication engineer. Again, it is only by establishing that the a.g.c. threshold occurs at that value of input which may be regarded as giving the minimum signal/noise ratio necessary for any particular service that the useful sensitivity can be discussed. For another type of service, however, e.g. the snap interception of signals, the mechanical characteristics of the receiver become directly relevant to the specification of sensitivity; for this type of service probably the most useful specification is a statement of the minimum input which can be appreciated when searching at a given rate of frequency coverage.

Eqn. (1) gives the noise across R before the load represented by the receiver is applied, as a function of bandwidth. Strictly speaking, the bandwidth is defined only after the receiver load is applied, i.e. by the selectivity of the receiver. It might be better to stress this point by referring to the r.m.s. open-circuit noise voltage over the pass-band under consideration.

Mr. D. Maurice: I am a newcomer to noise-factor consideration, but the following is a definition of it which I can understand:

$$N = \frac{\text{Total output noise power}}{\text{Output noise power due to source only}}$$

That is the same definition as that given by the authors, or a least it gives the same answer, but it is another way of lookin at the matter. I think it is very useful for the specification c v.h.f. receivers, but I have never tried to specify ordinary mediun wave or long-wave receivers in that way.

In Section 3.1.2, the authors say, "if hum is a limiting factc in determining the signal/noise ratio a suitable high-pass a. filter should be used." I should like to ask them whether the have considered using an aural weighting network for measurin the signal/noise ratio. The question of weighting networl is a very vexed one. Nobody knows what an ear really hear but I should be interested to know the authors' opinion. Fc instance, there are various internationally-accepted standar weighting networks, some for telephone circuits and some fc broadcast circuits. It would be valuable to have specified in receiver both the noise factor and the signal/noise ratio. seems to me that for the signal/noise ratio measurement, whe bandwidth comes into the problem, it would be of value to ha a fixed output bandwidth, something like the ear, so that whe listening to a high-fidelity receiver with an audio bandwidth c 50 c/s to 7 kc/s, there would be little deterioration in signal/noi ratio compared with that of a communication receiver with bandwidth of 5 c/s to 3 kc/s.

I have measured the balance of transformers, which for certai applications require a quite high degree of balance; the metho I have adopted is not quite the same as that shown in Fig. 6(*b* The circuit is shown in Fig: C and gave results which differed b

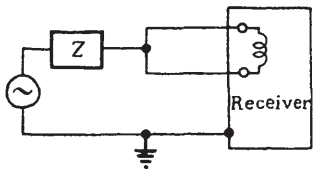

Fig. C

less than 1 db from those obtained by means of the method c Fig. 6.

I agree with Mr. Griffiths that Fig. 21 indicates a very fir receiver. It might give the impression that temperature con pensation of components always works like that, but that is n the case. I have seen curves like that of Fig. D, because tl

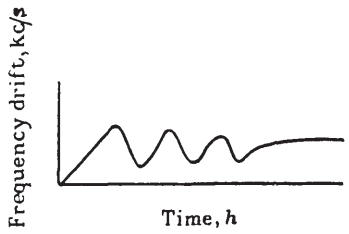

Fig. D

time over which the various temperature compensations tal place is not the same, and it is at times difficult to tell what due to mains variation and what is due to lack of equal-tin temperature compensation.

With regard to the measurement of automatic frequen control, there is one measurement which is not described in tl paper and which I have made on one or two receivers. Supposi a receiver is tuned to a station and the automatic frequen control is holding it more or less on that station, what streng

of interfering station will pull that receiver off the wanted station? The scheme that I have adopted is to make the wanted station a station of 1-mV strength, and to ask myself what strength a station 10 kc/s away would need to have in order to pull the receiver off the wanted 1-mV signal. In one case I found that the interfering signal 10 kc/s away had to be nine times the strength, i.e. 9 mV.

Major I. A. Jamieson: The tests outlined in the paper are really acceptance tests. From the Services' maintenance viewpoint, the most valuable tests are those on receiver characteristics which vary in time due to deterioration or drift of pre-set circuit components, and I should like these characteristics to be separated from those which are purely functions of initial design.

One essential test which has been omitted is a check on the reaction of the receiver to external noise. Noise-limiting circuits are of increasing importance in communication-type receivers.

I do not agree with the use of 400 c/s as a test modulation frequency. A mean speech frequency derived from immediate-appreciation curves should be employed, and a frequency of about 1 000 c/s is indicated. The frequency utilized should be the same as that selected for the testing of line equipment.

Mr. I. James: The signal/noise test is adequate for comparing two similar types of receiver, and I should not necessarily employ noise-factor measurement under these conditions, but I should like to mention one experience which we have had in connection with this measurement under normal production conditions, which unfortunately are not ideal for the measurement of signal/noise ratio. The general factory noise levels with which one has to contend make screened cages essential, but, unless these are very well designed, there are still great difficulties in obtaining reasonably good signal/noise ratios. For example, a signal/noise ratio may be set by the designer based on measurements made under very careful conditions, with a screened cage which he has checked, but when it comes to production testing somebody leaves the door open, and in these circumstances we have shown that the measured signal/noise ratios never meet those prescribed by the designer. We investigated this, and, after measuring the signal/noise ratio at different hours by day and night, in the factory noise and outside, we came to the conclusion that we could not measure signal/noise ratios inside the factory during the day which were within 2 db of those that we could measure outside. If there was any other way of measuring receiver performance which gave similar information it would be very useful, because both the signal/noise ratio and the noise factor measurements are subject to outside interference.

Mr. E. Phillips: I should like to draw attention to one part of the paper which, I think, has not been emphasized sufficiently. The performance of the receiver has been rightly said to be dependent mainly on the intermediate-frequency amplifier, but I feel that the tests which the authors require do not indicate the performance of this part of the equipment sufficiently.

With regard to Section 3.4.2, the audio-frequency response will depend very considerably, I think, on the input level at which the response is measured. This is inferred in Section 3.3.2, where reference is made to taking selectivity curves with the a.g.c. disconnected and with the use of a d.c. bias. Should not this procedure be adopted for measuring audio-frequency responses?

Another matter which I think should be investigated is the shift of frequency of the oscillator with input signal strength, which, in a poorly designed receiver, can be considerable.

Mr. G. S. Light: Consideration of test apparatus cannot be ignored in dealing with the subject of testing receivers. A previous speaker has mentioned that output meters do not always respond linearly to power, so that difficulties at once arise in measuring the signal/noise ratio. But more departure from the ideal is probably found in signal generators: they drift, they have frequency modulation, their output contains unwanted hum and noise, and the output voltage and frequency are only approximately as indicated.

A very vexed question which always arises in the testing of receivers concerns lack of standardization of the high-frequency "microvolt." Discrepancies of several decibels have been found between quite good instruments, regarded by their respective guardians practically as primary standards. I was once involved in a situation in which no less than six different receivers were being tested in the same place at the same time, to six different "microvolts" to the satisfaction of six separate authorities. If two micrometers, say, are found to differ, the discrepancy is resolvable by reference to slip gauges and, ultimately, to the N.P.L.'s national standard of length, but no equivalent procedure is available for high-frequency voltages. I should like to ask whether there is any prospect of this measurement being placed on a technical basis instead of an authoritarian one.

I wonder whether the authors make any provision for testing for hum modulation which occurs when receiving a high-frequency c.w. signal with the beat oscillator on. This appears in many receivers and can have a considerable effect on reception.

Dr. R. L. Smith-Rose: The B.S.I. Committee to which reference has been made in the discussion started work ten or twelve years ago, but its activities were suspended on the outbreak of war in 1939. The Committee has now revived its activities, and, with a new lease of life and a considerable amount of further knowledge and with the advantage of the work done by inter-Service establishments during the war, I think the Committee is now able to pursue its work with very much more hope of reaching the goal. But I am still a little apprehensive—and the discussion has made me even more apprehensive—about the kind of reception which the draft specification will have when it is issued.

I should like to warn you that any specification that will be useful must be limited in its scope and deal only with very basic facts. The Committee which sat before the war broke down first on a question of policy, but, even if that had not happened, I could see disaster ahead, because one member of the Committee was very keen on inter-modulation products, and at nearly every meeting he produced a new set of combinations of various frequencies. The Committee cannot pursue all the possible features of a receiver which may be of interest to a few people, but we have first to produce a document which will specify the main features of a receiver as a receiver, whatever its purpose and whatever its frequency range. Until we have got an agreed set of definitions as to what we want to measure and have agreed on some methods of testing, we shall not make any progress at all. We must first limit ourselves to the basic features, and then we can deal in an Appendix with the particular points that need to be catered for according to the use to which any particular class of receiver is put.